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EFFECTS OF THE LABYRINTHS ON THE CERVICAL MUSCLE TONUS

S. I. Stepanova

ABSTRACT. Demonstration that the electromyographic tonus of the sternocleidomastoid muscles of intact rabbits is equally strong on both sides and that it weakens considerably on the operated side and remains essentially unaffected on the intact side after unilateral labyrinthectomy. This observation is consistent with the findings of Magnus (1924).

It has been known for a long time that the labyrinths influence the muscles of the limbs and neck and, in some animals, the trunk muscles.

To express this relationship, Ewald (1892) introduced the concept of the "labyrinthotonus" of muscles into physiology and established an experimental basis for it. Later Magnus (1924) examined the mechanisms of this influence in more detail. He performed numerous experiments on guinea pigs, rabbits, cats, dogs and monkeys, and also examined neurological patients. As a result he showed that the labyrinths influence the tone of the limb and trunk muscles in two ways: directly and secondarily.

The direct influence is mediated by tonic labyrinthine reflexes; reflexes from one labyrinth act with equal strength on the limbs of both sides.

In rabbits and cats the labyrinths also have a direct influence on the trunk muscles.

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Magnus also observed that after unilateral labyrinthectomy a considerable weakening of the tone of the limbs on the side of operation takes place in all species of animals, and this effect lasts from a few hours to a few weeks depending on the species of animal. He interpreted it as a direct result of extirpation of the labyrinth, but could not connect it with the action of a definite labyrinthine reflex.

The secondary (in Magnus's words, very intensive) effect is mediated by the direct action of the labyrinths on the cervical muscles which, in turn, regulate the tone of the limb (and trunk in guinea pigs, dogs and monkeys) muscles through cervical tonic and stato-kinetic reflexes.

According to Magnus the labyrinths exert their influence on the neck muscles by means of tonic labyrinthine reflexes. One labyrinth influences only the ipsilateral cervical muscles. After removal of one labyrinth the tone of the

*Numbers in margin indicate pagination in foreign text.

neck muscles which rotate the neck and incline it to the side of the intact labyrinth disappears, regardless of their anatomical position on either side of the neck. As a result the classical signs of unilateral labyrinthectomy appear: rotation and inclination of the head primarily toward the side of the absent labyrinth.

Rotation of the head also takes place after exclusion of proprioceptive cervical reflexes, this being evidence of a direct influence of the labyrinths on the neck musculature.

Later investigations have mainly confirmed the connection between the muscles of different parts of the body and the labyrinths.

Fulton, Liddell and Rioch (1930), for instance, showed that injury to the vestibular nuclei in cats lowers the tone of the quadriceps femoris muscle on the side of injury. As a result of subsequent decerebration of these animals /121
the rigidity and the reflex of the quadriceps femoris muscle to stretching were much lower on the side of injury than on the intact side.

Bach and Magoun (1947) confirmed the observations of the previous workers: in decerebrate cats unilateral destruction of Deiters' nucleus causes disappearance of rigidity of the limb muscles on the side of injury.

According to the findings of Ward (1950), preliminary distruction of the vestibular nuclei on one side causes asymmetry of the subsequent decerebrate rigidity in a cat as follows: strong extension of the fore- and hind limbs on the side contralateral to the injury with rotation of the whole trunk to this side. Extensor rigidity on the homolateral side was much less marked.

Kempinsky and Ward (1950) studied the effect of unilateral division of the vestibular nerve on motor responses of the flexor and extensor of the leg caused by stimulation of the motor cortex in cats. As a result a marked decrease or, in many cases, disappearance of the background movements of the limbs was found on both sides.

Gernandt and Thulin (1953) showed that each vestibular apparatus has an equally strong facilitatory influence on the spinal monosynaptic reflex of the leg flexors, the intensity of which diminishes appreciably on both sides after unilateral division of the vestibular nerve.

Data obtained by all these authors confirm Magnus's conclusion that the influence on each labyrinth on the limb muscles is equally strong on both sides. In their opinion, this influence is effected through the facilitatory region of the reticular formation along the reticulo-spinal tract. The vestibulospinal tracts are known to be uncrossed. The work of Ferraro, Pacella and Barrera (1940), of Lorente de No (1933) and others has proved the existence of numerous anatomical connections between the vestibular nuclei of both sides and the reticular formation. In addition, the work of Gernandt /122
and Thulin has shown that local destruction of the funiculus ventralis in the lower thoracic or upper lumbar divisions, interrupting the vestibulospinal tract, has only a very slight action, and in many cases no action at all, on a tested spinal reflex.

Gernandt and Thulin also showed that stimulation of the horizontal semicircular canals in cats by rotation usually leads to a generalized strengthening of the tone of the limb muscles. Only in decerebrate cats in indiviudal cases is a marked reciprocal effect observed, disappearing after unilateral division of the vestibular nerve. These workers consider that the vestibular apparatus may also exercise reciprocal control over activity of the muscles through the reticular formation.

Molnar (1958) fully confirmed the findings of Gernandt and Thulin. He showed that as a result of stimulation of the semicircular canals of cats in a state of decerebrate rigidity by rotation, and also simultaneously with stimulation of the motor cortex, a generalized contraction of the muscles of the limbs and neck is observed. Only in "especially favorable conditions" did Molnar observe reciprocal relationships between the flexors and extensors of the limbs, and also between the muscles on the right and left sides of the neck. Unilateral division of the vestibular nerve disturbed these reciprocal relationships and led to development of a generalized response from the muscles of the limbs and neck. I. Ya. Kalinobskaya and Yu. S. Yusevich (1963) studied the effect of unilateral caloric stimulation of the vestibular apparatus on the electrical activity of the limb and neck muscles in 8 healthy persons. As a result of stimulation the tone and electrical activity of the muscles increased on both sides, but in some cases to a greater degree on the side of stimulation.

In most of the works cited above data relating to the influence of the labyrinths on the limb muscles are given.

In the investigation now to be described, the influence of the vestibular apparatus on the tone of the sterno-cleido-mastoid muscles and the long spinal muscles was studied. The work was carried out on rabbits. As /123
Magnus (1924) showed, rotation and inclination of the rabbit's head take place as a result of the activity of paired muscles: the sterno-cleido-mastoid, the longus colli muscle, and the six occipital muscles: the four recti and the two oblique. The long spinal muscles take part in rotation of the trunk in the lumbar region.

Method. The animals were delabyrinthized unilaterally by Valentine's operation as described in Krause's monograph (1868). While the EMG was being recorded the rabbits wore a special overall and were fixed by its straps to a stationary support. The biopotentials of the muscles to be tested were recorded by leads applied to the skin surface (the "global" method of Yu. S. Yusevich, 1963). Yusevich states that "global" electromyography is a more adequate procedure for determining muscle function than the "local" method. The fact that in the global method no painful stimuli are applied to the animal, capable of producing reflex changes in the tone of the muscle to be tested, was important in our investigations. As Yusevich points out, electrophysiologists observe that even after a single insertion of a needle the reflex increase in tonic contraction of the muscle arising at the moment of puncture persists after removal of the needle.

Circular silver electrodes 8 mm in diameter were used to record the biopotentials. In the neck one electrode was applied to the point of attachment of the sterno-cleido-mastoid muscle to the mastoid process, and the other 2

cm away from the first along the line of the muscle. To record the EMG of the long spinal muscles one electrode was applied at the level of the 12th rib, the other 2 cm posteriorly to the first.

The skin at each point of application of the electrode was carefully shaved, leaving a hair-covered area between them. In this way the points of application of the electrodes were strictly standardized. When taking the EMG, the skin surface was coated with contact paste.

To prevent possible changes in tone of the investigated muscles as a result of application of the electrodes, we recorded the EMG 5 min after their application.

The EMG was recorded on a "Galileo" ink-writing electrocardiograph with electroencephalographic attachment. /124

The winding speed of the paper tape during recording was 100 mm/sec, and the amplification used was from 100 to 25 μV/cm. The filters and time constant were chosen so as to reduce distortion to the minimum.

We were of the opinion that an ink-writing oscillograph could be used for recording the EMG in this case, despite the fact that under these circumstances the frequency of the muscle potentials as recorded by no means always corresponds to their true frequency.

There are definite indications in the literature (R. S. Person, 1962) that the frequency of the EMG should not be used to assess muscle function, for a relationship between muscle function and frequency of the EMG exists only in particularly rare cases. Moreover, under these conditions of recording, muscle function may be assessed from the amplitude of the waves on the electromyogram.

For the quantitative estimation of amplitude we used the method suggested by V. V. Usov (1961) for EEG analysis. The magnitude of the extreme amplitude values is measured. The magnitude of the extreme amplitude values was taken to be the distance between two lines corresponding to the greatest positive and greatest negative values of the potentials in a time interval always of 0.1 sec.

It was impossible to choose the time interval in accordance with the frequency of the potentials, as Usov recommends, for the following reasons: a) as already mentioned, the true frequency of the muscle potentials could not be judged from the frequency recorded on the EMG; b) the frequency of the biopotentials on the EMG was difficult, and often impossible, to sound correctly because of the very low amplitude of many of the peaks.

Since we digressed essentially from the method recommended by Usov, we had to assess its suitability in the modified form.

Statistical analysis of the distribution of the extreme amplitude values of the EMG showed that their distribution is regular and close to normal. The histogram of distribution of the extreme amplitude values for 200 readings is shown in Fig. 1 and compared with the theoretical normal distribution curve. /125

The arithmetic mean defines this type of distribution completely. To characterize the EMGs we used the arithmetic mean of 30 extreme amplitude values (V.V. Usov, 1961).

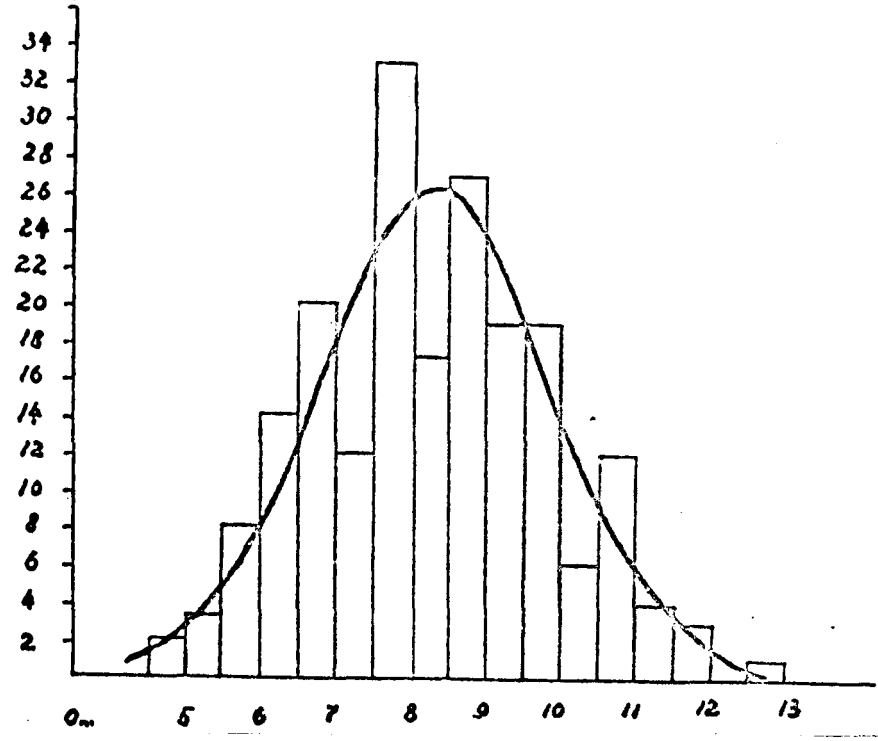

Figure 1. Histogram of distribution of extreme amplitude values for 200 readings compared with theoretically calculated normal distribution curve. Abscissa: extreme values of amplitude in mm. Ordinate: frequency.

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RESULTS

Altogether 5 delabyrinthized rabbits were studied (operation on the left labyrinth in all cases) and 4 intact animals were used as controls.

The experimental rabbits were studied at the following times after operation:

No. 1: from the 8th to the 10th month after operation,
No. 2: during the 9th month after operation,
No. 3: during the 1st week after operation,
No. 4: during the 7th month after operation,
No. 5: from the 3rd to the 5th month after operation.

In the course of the investigation of the tome of the sterno-cleido-mastoid muscles, 16 tests were performed on the delabyrinthized and 16 on the intact

rabbits. Comparative data for the tone of the sterno-cleido-mastoid muscles in the delabyrinthized and intact rabbits are given in Fig. 2 and the results of their statistical analysis in Table 1.

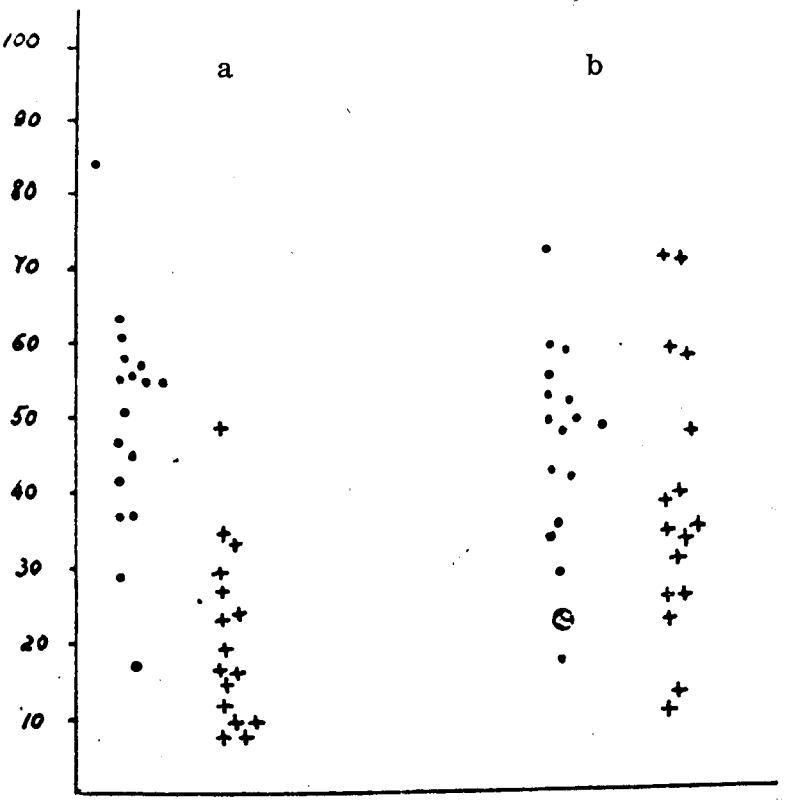

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Figure 2. Amplitudes of electromyograms of the sterno-cleido-mastoid muscles in μV: a) left, b) right; •, in intact rabbits; +, in delabyrinthized rabbits.

As might be expected, there was no difference in electromyographic tone of the right and left sterno-cleido-mastoid muscles in the intact rabbits. Likewise there was no difference in the tone of this muscle in the intact and delabyrinthized rabbits on the right (the sound) side.

The tone of the left sterno-cleido-mastoid muscle was much lower in the delabyrinthized rabbits than in the intact (difference 27.1 ± 15.5 μ V, probability 99.9%). Marked asymmetry of tone of the sterno-cleido-mastoid muscle was thus present in the delabyrinthized rabbits: it was greater on the right than on the left by 18.76 ± 13.0 μ V, with a probability of 99.9%. /128

Hence, as a result of unilateral delabyrinthization, no essential changes were found in the tone of the sterno-cleido-mastoid muscle on the sound side; however, a very significant decrease in the tone of this muscle was found on the side of the operation.

TABLE 1. Results of Statistical Analysis of Comparative Data for Tone of Sterno-Cleido-Mastoid Muscles in Delabyrinthized and Intact Rabbits

Details of Values Compared	Number of observations (n)	Arithmetic mean of difference with its mean error $\bar{X}\pm m$	Value obtained t	Value of t from tables with probability 95%	Value of t from tables with probability 99.9%	Qualitative assessment of significance of difference	Confidence intervals for probability 99.9%
Amplitude of EMG in intact rabbits (left)	16	0.009 $\pm$ 1.86	0.049	2.13	4.07	difference not significant	
Amplitude of EMG in intact rabbits (right)	16						
Amplitude of EMG in delabyrinthized rabbits (left)	16	18.76 $\pm$ 3.2	5.86	2.13	4.07	difference significant	18.76 μV $\pm$ 13 μV, i.e. from 5.8 μV to 31.8 μV
Amplitude of EMG in delabyrinthized rabbits (right)	16						
Amplitude of EMG in intact rabbits (left)	16	27.1 $\pm$ 4.25	6.4	2.04	3.65	difference highly significant	27.1 μV $\pm$ 15.5 μV, i.e., from 11.6 μV to 42.6 μV
Amplitude of EMG in delabyrinthized rabbits (left)	16						
Amplitude of EMG in intact rabbits (right)	16	7.6 $\pm$ 5.69	1.34	2.04	3.65	difference not significant	
Amplitude of EMG in delabyrinthized rabbits (right)	16						

NOTE. Amplitude of EMGs given in μV

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Contraction of the sterno-cleido-mastoid muscle in the rabbit rotates the head to the same side (A. A. Ternet'ev, 1952). However, after unilateral delabyrinthization the tone of the sterno-cleido-mastoid muscle on the side toward which the head rotates and inclines is lowered.

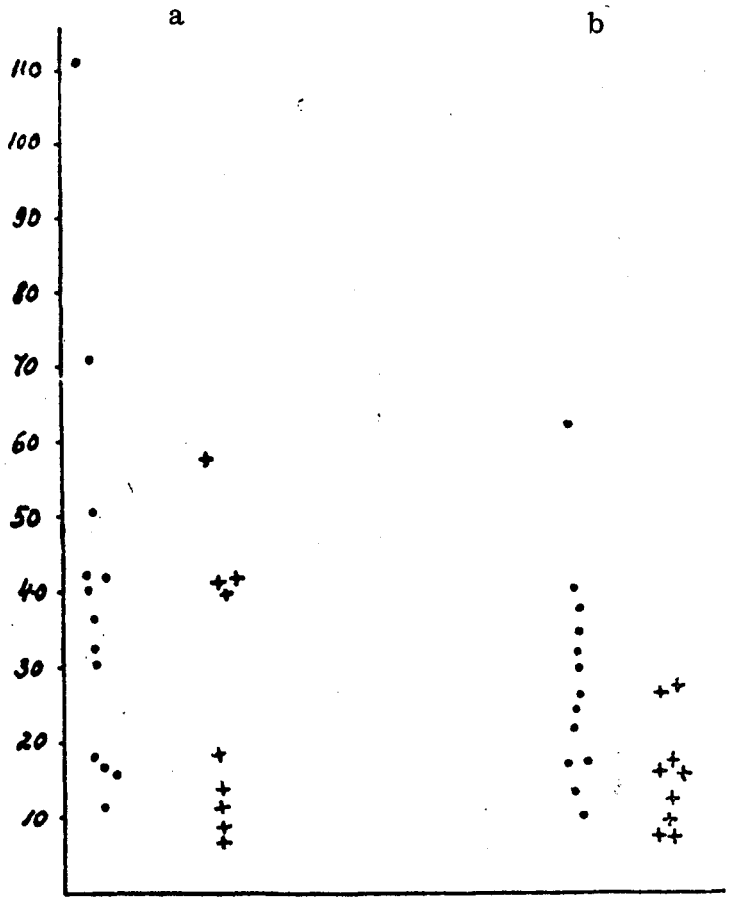

Figure 3. Amplitudes of electromyograms of long spinal muscles in μV: a) left, b) right; •, in intact rabbits; +, in delabyrinthized rabbits.

Evidently the inclination and rotation of the head in this case take place on account of a redistribution of tone of the more powerful and numerous posterior cervical muscles.

The degree of rotation and inclination of the head in the delabyrinthized animals varied with the time elapsing after operation (rotation of head from 90 to 15-20°). We do not consider that our material is adequate for establishing a relationship between the degree of rotation and inclination of the head and the magnitude of the tone of the sterno-cleido-mastoid muscle.

During investigation of the tone of the long spinal muscles 13 tests were carried out on intact rabbits and 9 on delabyrinthized rabbits. The results of the tests were given in Fig. 3.

No statistically significant changes in the tone of these muscles were obtained after unilateral delabyrinthization. This result may have been due to technical errors: when taking the EMG we fixed the rabbit too rigidly in the lumbar region, as a result of which the natural distribution of tone of these muscles was disturbed.

The results obtained are in agreement with Magnus's conclusions regarding the unilateral influence of the labyrinths on tone of the neck muscles.

CONCLUSIONS

1. The electromyographic tone of the sterno-cleido-mastoid muscles of intact rabbits is the same on the right and left sides.
2. Unilateral division of the 8th nerve causes a marked decrease in tone of the sterno-cleido-mastoid muscle on the side of the operation.
3. The tone of the sterno-cleido-mastoid muscle on the sound side is not significantly changed after unilateral delabyrinthization.
4. The results are evidence in favor of the unilateral influence of the labyrinths on tone of the sterno-cleido-mastoid muscle.

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